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# Gondwana Sequence of the northern Pranhita-Godavari Valley : its stratigraphy and vertebrate faunas

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The Gondwana Sequence in the northern part of the Pranhita-Godavari Valley consists of four formations of the Lower Gondwana and seven formations of the Upper Gondwana. The gross lithological characters and mappability are considered as the major criteria for delineating the formations. The name Kamthi Formation which has been used by different authors in different senses, is here used in the sense of Sengupta (1970). The rocks between the Barakar and this Kamthi are divided into four lithozones for limitations of mappability. Although some of these lithozones have earlier been designated as formations, at present not sufficient information is available to justify this. Only two breaks, both within the Upper Gondwana, are found to be present; there is no recognisable break between the Lower and the Upper Gondwana. A summary of this succession is presented in tabular form taking into account the works of earlier authors. The alternative views that are radically different from the one presented here are also discussed briefly. The usefulness of plant megafossils and fossil vertebrates in understanding the stratigraphy is discussed briefly and their role in determining the possible geological ages of some of the formations is mentioned.

The vertebrate fauna from a number of formations is listed. At least seven formations are fossiliferous as far as vertebrates are concerned. Of these, two belonging to the Triassic and one belonging to the Jurassic are quite well-documented. The other four are less well-known, but serve as very useful time markers. All these vertebrate-bearing formations can be correlated with co-eval rocks elsewhere in the world. The difficulty of correlating continental deposits is realised and keeping this in view a tentative correlation is presented.

**Key-words**—Stratigraphy, Pranhita-Godavari Valley, Vertebrate fauna, Gondwana Sequence.

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## साराँश

### उत्तरी प्रणहिता-गोदावरी घाटी का गोंडवाना अनुक्रम : इसका स्तरविन्यास एवं रीढ़धारी जीवजात

टी० एँस० कुट्टी, एँस० एँल० जैन एवं टी० रॉय चौधरी

प्रणहिता-गोदावरी घाटी के उत्तरी भाग में गोंडवाना अनुक्रम में अधरि गोंडवाना के चार तथा उपरि गोंडवाना के सात शैल-समूह विद्यमान हैं। समस्त शैलिकीय संलक्षणों आदि का शैल-समूहों के परिसीमन में प्रयोग किया गया है। 'कामथी शैल-समूह', जो कि विभिन्न शोध-कर्त्ताओं ने विभिन्न रूप से प्रयोग किया है, शब्द को इस शोध-पत्र में केवल सेनगुप्त (1970) के अनुसार ही प्रयोग किया गया है। बराकार एवं कामथी के मध्य स्थित चट्टानों को मानचित्र परिसीमन हेतु चार शैल-मंडलों में विभक्त किया गया है। यद्यपि इन शैल-मंडलों में से कुछ को शैल-समूहों के रूप में नामांकित किया गया था परन्तु पर्याप्त जानकारी के अभाव में ऐसा करना संभव नहीं है। उपरि गोंडवाना में ही दो दरारें प्रेक्षित की गई हैं; परन्तु अधरि एवं उपरि गोंडवाना में इस प्रकार का कोई अपभ्रंश नहीं मिलता। इस अनुक्रम पर अब तक किये गये शोध-कार्य को एक सारणी के रूप में प्रस्तुत किया गया है। एक दूसरे से भिन्न मतों को भी संक्षिप्त रूप में प्रस्तुत किया गया है। स्तरविन्यास को जानने हेतु गुरुपादपाश्मों एवं अश्मित रीढ़धारीयों का महत्त्व भी विवेचित किया गया है। कुछ शैल-समूहों की सम्भाव्य भूवैज्ञानिक आयु सुनिश्चित करने में इनकी भूमिका का भी उल्लेख किया गया है।

अनेक शैल-समूहों से उपलब्ध रीढ़धारी जीवजात एक तालिका के रूप में प्रस्तुत किया गया है। जहां तक रीढ़धारीयों का प्रश्न है कम से कम ऐसी सात शैल-समूह जीवाश्ममय हैं जिनमें से दो त्रिसंघी कल्प की तथा एक जूराई कल्प की शैल-समूहों का विस्तृत विवेचन किया गया है। अन्य चार इतनी सुविदित नहीं हैं परन्तु आयु निर्धारण में इनका महत्वपूर्ण योगदान है। इन सभी रीढ़धारी शैल-समूहों का विश्व की अन्य समकालीन चट्टानों से सहसम्बन्धन किया जा सकता है। महाद्वीपीय निक्षेपों के सहसम्बन्धन में आने वाली कठिनाइयों को प्रस्तुत किया गया है तथा इसी दृष्टिकोण को ध्यान में रखते हुए अस्थायी सहसम्बन्धन प्रदर्शित किया गया है।

Concepts, limits and extension of the Indian Gondwana
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THE Pranhita-Godavari Valley (PG Valley) contains not only one of the largest Gondwana basins of India but also gives the most complete succession of Gondwana rocks. The basin forms a part of a series of NW-SE trending Gondwana basins that form the southern arm of the subtriangular Main Gondwana Province of the peninsular India (Robinson, 1970).

The oldest Gondwana rocks of the PG Valley rest mostly on the Pakhal and Sullavai supergroups while the younger part of the succession is cut-off by a great boundary fault running more or less parallel to the strike of these rocks which brings them against the same Proterozoic rocks. At the north-western end of the valley the Gondwana sediments are partly covered by the Deccan Traps and partly followed by the Wardha Valley Gondwana, though separated by a prominent fault. In the south and southeast these rocks are partly represented by the marine and lagoonal Gondwana sediments of the Coromandel Coast and overlain by the recent alluvial deposits of Godavari and Krishna deltas.

The present area has been chosen to serve as a standard for the entire valley because this part has the most complete succession of the Gondwana rocks and has been a happy hunting ground for geologists and palaeontologists for over a century and a half. A geological map of the area bounded by Peddavagu in the north and Godavari River in the south is also presented to explain the stratigraphic interpretation put forward in this paper (Map 1).

## STRATIGRAPHY

Geological accounts on the PG Valley started appearing from the second quarter of the last century (Voysey, 1833 (*in* King, 1881), occurrence of sandstones and hot springs; Walker, 1841, search for coal and discovery of fossils; Hislop, 1864, discovery of fossils; Oldham, 1859, occurrence of fossils and Gondwana rocks; Jones, 1863, occurrence of ***Estheria***; Blanford, 1871, occurrence of coal seams; Hughes, 1877, geological account of the area adjacent to the Wardha Valley Coalfield; Egerton, 1878, description of ganoid fishes; Feistmantel, 1879, description of 'Kota Flora'). It was left to King (1881) to give the first detailed account of the geology of the PG Valley that included a stratigraphic description supported by a geological map of the valley. He subdivided the Gondwana rocks into Lower and Upper divisions; each of which was in turn subdivided into stratigraphic units, generally speaking, in consonance with the Gondwana stratigraphic successions found elsewhere in peninsular India. The Lower Gondwana contained three units—Talchir, Barakar and Kamthi while the Upper Gondwana were also subdivided into three units—Maleri, Kota and Chikiala. It may be mentioned here that all the stratigraphic units recognised by King (1881) were thought to show unconformable relationship with the underlying and overlying units respectively.

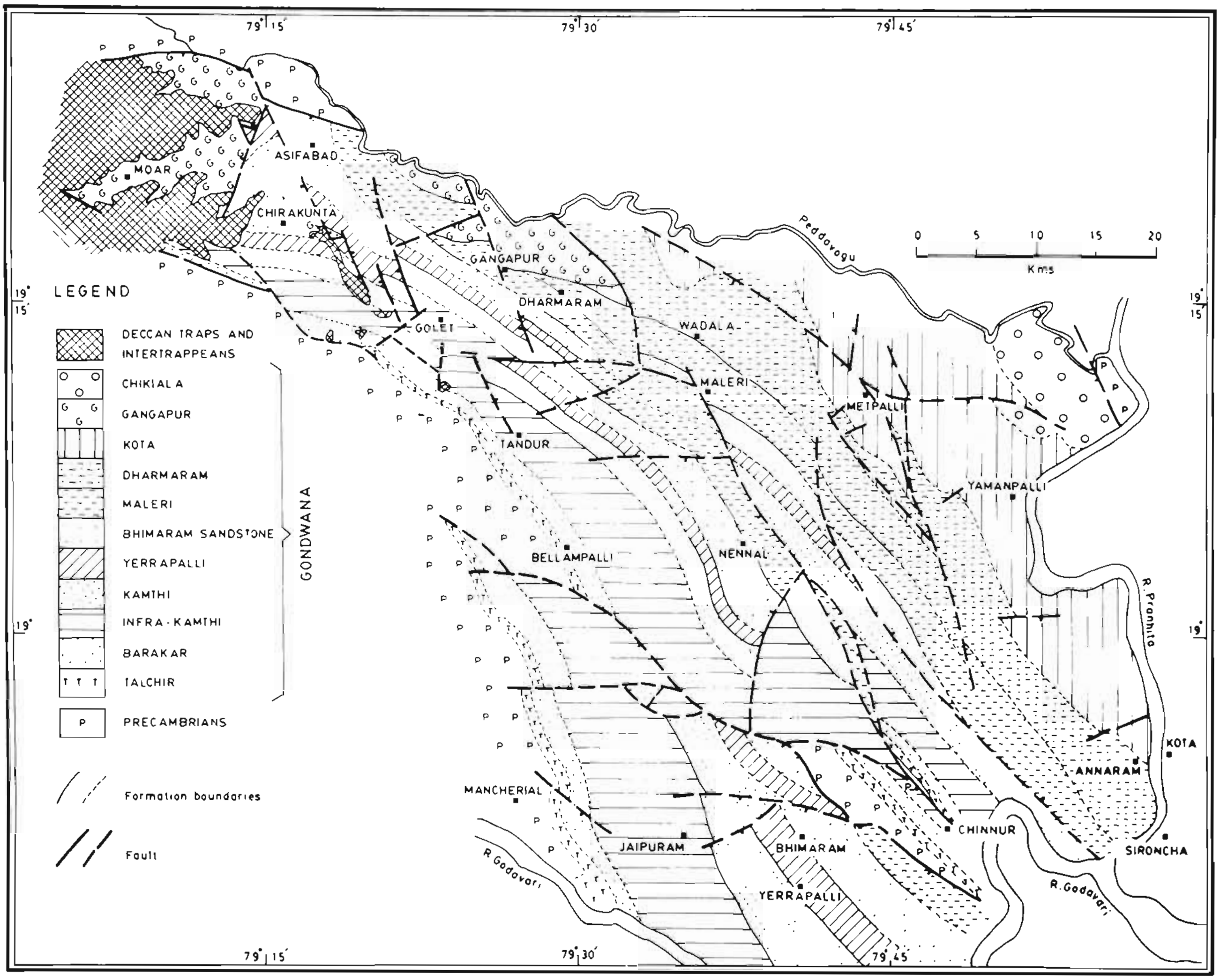
Heron (1949) published a geological map of the area, in which the stress was perhaps more on the Precambrians. He observed that the western boundary of the Gondwana south of Sirpur and its western continuation into the Jangaon Valley (that is the northern boundary in this part of the outcrop) were faulted boundaries. A consequence of this observation was the removal of some of the evidence on which King concluded that the lower boundaries of his Barakar and Kamthi were marked by unconformities.

Coal exploration work continued right through this period, the emphasis had been on their exploitation and on studies related to resource availability. Perhaps as a consequence, in spite of the potential possibilities, these studies did not lead to a better description of the Barakar nor to a publication of a more accurate and detailed map.

A clearer picture of the Maleri fauna emerged through the works of Lydekker (1885), Huene (1940) and Colbert (1958). This fauna comprised a metoposaurid amphibian, a rhynchosaur *Paradapedon* (*Hyperodapedon*), a phytosaur *Parasuchus*, perhaps three more forms of phytosaurs, an armoured pseudosuchian and some early dinosaurs. It afforded a ready correlation with similar faunas from Europe and North America of Late Triassic age.

The apparent stunted progress during the above period was due, to a great extent, to the practical difficulties in understanding the true geology of the area. It reflects the broad resemblances that are seen among the lithologies of different formations and therefore the problems in recognising the formations, the compounding of these problems because of the difficulties in recognising the many faults that exist but leave little trace on these lithologies, and at the same time, the need to understand and map the succession in much more detail to surmount the above problems.

During last 25 odd years, the Indian Statistical Institute under the leadership of Dr Pamela Lamplugh Robinson, University College, London, the Geological Survey of India (GSI) and the Oil and Natural Gas Commission (ONGC) have carried out independent work in this area which have resulted in a revised stratigraphic column and a geological map. There are thus three different versions of the geology of this area under consideration. The work of the GSI (Rao, 1982) and the present work are in some sense complementary, but the version of the




**Map 1**—Geological map of the Gondwanas of the northern Pranhita-Godavari Valley between Pedda Vagu and the Godavari River (incorporating data from Chatterjee, C. 1967; Kutty, T. S., 1969; Sengupta, S., 1970; Rudra, D. K., 1982; Rao, C. S. R., 1982; Bandyopadhyay, S. & Rudra, D. K., 1985; and Sengupta, D., under preparation). The regional dip of the beds is generally about 10°-15° to NNE or NE; Gangapur and the Chikiala have lower dips, sometimes subhorizontal; the Deccan Traps are practically horizontal.

ONGC (Raivarman *et al.*, 1985) is vastly different. For this reason, in the following section the revisions of Raivarman *et al.* (1985) have not been incorporated, but are discussed separately in a subsequent section.

It is necessary to point out that many stratigraphic names have been used by different authors in different senses. In the discussions that follow it may often be necessary to use a name in the sense as used by a specific author. In such cases the reference is explicitly stated unless the implication is obvious. Unqualified references generally imply their current revised sense as given in Table 1.

### Talchir Formation

The Talchir Formation is the oldest of the Gondwana formations of the area. It rests unconformably on an eroded surface of Precambrian rocks. It is believed to represent sediments laid down under a glacial or glacio-fluvial regime.

The Talchir Formation crops out as a narrow strip, broken at places by faults and never attaining any great thickness, along the western margin of the basin. A good section near Mancherial exhibits tillites at the base (Sullavai Supergroup) consisting of polymictic clasts of granite, quartzite and limestone set in a fabric of mixed grain size. The tillites grade upward into a succession of greenish shales and siltstones. The siltstones are succeeded by another unit of structureless tillites which, in turn, are overlain by fine-to medium-grained cross-bedded sandstones. This area thus records recurrence of tillites (*see* Rao, 1982).

**Table 1—Revised Gondwana Sequence of the northern Pranhita-Godavari Valley**

| FORMATION | MAIN LITHOLOGIES | IMPORTANT FOSSILS | AGE |
|---|---|---|---|
| DECCAN TRAPS | | | LATE CRETACEOUS & EARLY TERTIARY |
| Chikiala | Highly ferruginous sandstones and conglomerates | ? | ? |
| Gangapur | Coarse gritty sandstones; greywhite to pinkish mudstones with interbedded ferruginous sandstones and concretions | *Gleichenia, Pagiophyllum Ptilophyllum, Elatocladus* | Early Cretaceous |
| Kota | Sandstones, siltstones and clays with a characteristic limestone band | Holostean fishes Sauropods, Pterosaurs Early mammals | Early Jurassic |
| Dharmaram | Coarse sandstones and red clays | Prosauropods (small & large) | late Late Triassic |
| Maleri | Red clays, fine to medium sandstones and lime-pellet rocks | Metoposaurs Phytosaurs Rhynchosaurs Aetosaurs | early Late Triassic |
| Bhimaram Sandstone | Medium to coarse and fine sandstones, ferruginous in the lower part and calcareous in the upper part; some red clays | Labyrinthodont Dicynodont | ? (late Middle) (Triassic |
| Yerrapalli | Mainly red and violet clays with sandstones and lime-pellet rocks | Stahleckeriid & Kannemeyeriid dicynodonts | early Middle Triassic |
| Kamthi | Ferruginous non-feldspathic or slightly feldspathic sandstones and purplish siltstones | Dicynodont from basal beds | late Late Permian to Early Triassic |
| Infra Kamthi | 4 lithozones; zone 2 is carbonaceous; zones 3 and 4 with red mudstones, latter also has limonitic shales | Endothiodont Cistecephalid (from lithozone 3) | Late Permian and ? very late Early Permian |
| Barakar | Feldspathic sandstones, carbonaceous shales and coal | Glossopteris flora | late Early Permian |
| Talchir | Tillites, greenish shales and sandstones | | early Early Permian |
| PRECAMBRIANS | | (PROTEROZOIC) | |

### Barakar and Kamthi of King

The succession above the Talchir and up to the top of the Kamthi of King has been interpreted by different authors in different ways. King's Barakar consists essentially of the coal-bearing group of rocks that overlie the Talchir. More or less the same definition seems to have been adopted by Rao (1982) and Ramanamurty (1985). They recognised a second carbonaceous sequence higher up, and called the intervening beds the Barren Measures, restricting the name Kamthi to the remaining part of this succession. Sengupta (1966, 1970) observed that the sandstones and associated siltstones in the upper part of King's Kamthi were lithologically distinct and distinguishable from the succession below, and therefore restricted the name Kamthi to this upper part only. Though Sengupta's study covered only a relatively small area, the mapping of Chatterjee (1967) and our own observations confirm that the Kamthi, in this revised sense, remains essentially distinct throughout the area under consideration here. Though lateral variations are present, its identity is maintained. In view of the essential similarities of the sandstones of the succession above the Talchir and up to his Kamthi, Sengupta included this entire succession in his Barakar, except for some shales, which he called the Ironstone Shales, that occurred impersistently between them.

We have accepted here the definition of Barakar as used by King (1881) and as also by Rao (1982). We shall use the name Kamthi here in the sense of Sengupta (1970), as its lithological distinctness will

**Table 2—Lithostratigraphic interpretations of the Lower Gondwanas of northern Pranhita-Godavari Valley**

| King (1881) | Sengupta (1970) | | Raja Rao (1982) | | This Paper | | Lithological characteristics | |
|---|---|---|---|---|---|---|---|---|
| KAMTHI | KAMTHI | Upper Member | KAMTHI | Upper Member | KAMTHI | Upper Member | Ferruginous non-feldspathic sandstones & | abundant pebbles, few siltstone clasts |
| | | Middle Member | | | | Middle Member | | abundant siltstone clasts, few pebbles |
| | | Lower Member | | | | Lower Member | | purplish siltstones |
| | IRONSTONE SHALES | | | Middle Member | INFRA-KAMTHI | Lithozone 4 | Essentially feldspathic, calcareous or sometimes ferruginous sandstones & | red mudstones, limonitic shales, purplish siltstones |
| | BARAKAR | | | | | Lithozone 3 | | red, green & yellow mudstones and shales |
| | | | | Lower Member | | Lithozone 2 | | carbonaceous or coaly shales & thin coals |
| | | | BARREN MEASURES | | | Lithozone 1 | | shales with insignificant carbonaceous matter |
| BARAKAR | | | BARAKAR | | BARAKAR | | | carbonaceous shales and coal |
| TALCHIR | | | | | | | Tillites, green shales and sandstones | |

then give it an identity of its own. The succession between the Barakar and Kamthi so defined requires, in our opinion, much more information before it can be sorted out. We have therefore preferred to use an informal name 'Infra-Kamthi' to refer to them. However, there are indications to suggest the existence of four lithozones within it, but the information available is too insufficient to give them any formal stratigraphic status at present. These varied use of the different stratigraphic names and their correspondence are summarised in Table 2. The succession is briefly described below.

### Barakar Formation

The Barakar succeeds the Talchir Formation without any apparent break and consists of coarse gritty calcareous sandstones, greywhite or yellowish in colour and having pebble bands. They are associated with finer grades of sandstones and shales, and characteristically, much of the shales in this suite are carbonaceous. Perhaps the most important member of this suite is the coal, which is widely mined and is of considerable economic importance.

Much of the details of this formation are known only from bore-hole data. Although exposures of the carbonaceous shales and coal are known they are not all that common. The fine sediments yield good plant fossils.

### Infra-Kamthi

*Lithozone-1*—This consists of a succession of coarse sandstones broadly similar in character to those of the Barakar. The sandstones may be ferruginous and brown in colour; there are interbedded shales, but there is no coal nor any significant carbonaceous matter in this suite. The information leading to the recognition of this lithozone and the next one comes from bore-hole data.

*Lithozone-2*—This lithozone also consists of sandstones and shales like in the previous lithozone, but is distinguished from the latter by the presence of carbonaceous shales, coaly shales and may be some coal.

*Lithozone-3*—This consists of a succession of brownish, yellowish or grey feldspathic sandstones with interbedded lenses and bands of mudstones and shales. The sandstones are generally calcareous but may be ferruginous in places. No carbonaceous shales or coal is known from this lithozone.

Very broadly the succession can be thought of as succession of cycles, each cycle consisting of all or some of sandstones, mudstones and shales. However some clarifications are called for. Two traverses taken not too close to each other are unlikely to produce sections which will allow a one-to-one correspondence of their individual units. If the traverses are sufficiently apart such matching may become highly speculative. There is no work yet which brings out the inter-relationships of these units. It is thus evident that the units of these cycles, and perhaps the cycles themselves, are not traceable laterally for any considerable distance.

*Lithozone-4*—This lithozone is, in a sense, a special case of the previous one in that the shales are brown in colour, fissile, and micaceous with haematite or limonite cement. There may also be some purplish siltstones in some of the cycles. These fissile shales sometimes yield plant fossils.

It will be useful at this stage to consider the following points about the lithozones of the Infra-Kamthi: (1) the exposures of the rocks of these lithozones, except perhaps lithozone 4, are predominantly of sandstones which, as we have noted, have basically similar characters; (2) the essential characters of lithozones 1 and 2 are known only from subsurface data. This is especially true of the characters that distinguish lithozones 2, that is the presence of carbonaceous shales and coaly shales or coal in it. There is at present no clear indication as to how to distinguish these lithozones on the basis of surface characters; (3) the lithozones 3 and 4 are inferred from surface exposures, but, exposures being poor generally, their mappability or even the possibility of defining recognisable boundaries for them (except the upper boundary of lithozone 4) are yet uncertain.

It can only be concluded therefore that these lithozones are not amenable to surface mapping with the information that is available at present. Hence they are best kept as a single unit, at least for the time being. Even the definition of a recognisable upper boundary for the Barakar Formation, for surface mapping, is a difficult proposition. Under the circumstances we prefer to lump them together under a tentative informal name like Infra-Kamthi, until more detailed information becomes available.

### Kamthi Formation

*Lower Member*—This consists of fine- to medium-grained poorly sorted sandstones which are non-feldspathic and ferruginous, and are associated with lenses and bands of purplish siltstones. In the southern part of this area a thick purplish siltstone forms a characteristic basal horizon.

*Middle Member*—It consists of a sequence of coarse ferruginous loosely cemented sandstones containing numerous siltstone clasts; interbedded with them there may also be thin lenses or partings of the siltstones.

*Upper Member*—Above this and up to the top of the Kamthi (King) the sequence consists of coarse poorly sorted brown non-feldspathic ferruginous pebbly sandstones, with pebble bands and occasional clasts of siltstones.

### Post-Kamthi succession

According to King (1881) this succession has three formations—Maleri, Kota and Chikiala. The Maleri Formation was known to have a Late Triassic vertebrate fauna whereas the Kota Formation had an Early Jurassic vertebrate (fish) fauna. The Maleri was a dominantly clay formation whereas the Kota was predominantly of sandstones with, characteristically, some limestones in it. Yet, their delineation into two separate formations had been so difficult that they were at one time considered to form an inseparable unit and known as the Kota-Maleri (or Maledi) beds. The situation was more confusing because of the occurrence of some plant fossils judged to be younger in age than the Kota fauna, but occuring in beds which were thought to be below those which yielded the fauna. What is more, some of the plant localities stated were well within the Maleri outcrop in King's geological map (Fox, 1931).

Detailed mapping of the area during recent years necessitated the recognition of a number of new formations and also help clarify many of these problems and confusions surrounding the Maleri and Kota formations of King. In the process the Maleri and the Kota were redefined and, in their current usage, carry a more restricted sense than what King had used (*see* Kutty, 1969; Sengupta, 1970).

The Maleri and Kota formations derive their name after the villages of the same names around which their characteristic lithologies and fauna were initially recognised. The extensive red clays and associated subordinate sandstones yielded its characteristic fauna which included the rhynchosaur *Paradapedon* (*Hyperodapedon*) and the phytosaur *Parasuchus*. The limestones that are characteristic of the Kota Formation yielded a fish fauna consisting of *Lepidotes*, *Paradapedium* (*Dapedium*) and *Tetragonolepis*. Over the years, the names Maleri and Kota have become intimately associated with both their lithological characteristics as well as their faunas.

The information that has now accumulated demonstrates that the geology of the area is vastly different from the picture that King visualised. The 'Gangapur beds' in its type area, which were thought by King (1881) to form basal beds of the Kota and which yielded plant fossils, were shown to overlie limestones and associated beds of the Kota Formation with an angular unconformity, necessitating a redefinition of the latter (Kutty, 1969). The succession between the Kamthi and the redefined Kota Formation is an essentially unbroken one except, perhaps, for a minor break at the base of the Kota. A total of four formations, not just one, were recognised and mapped within this succession. The name Maleri Formation was restricted to one of them on lithological and faunal considerations (*see* Jain *et al*., 1964; Kutty, 1969). It has also become abundantly clear that the geology of this area cannot be properly understood unless and until these formations are mapped.

The post-Kamthi succession, as it stands now, contains the formations Yerrapalli, Bhimaram Sandstone, Maleri, Dharmaram and Kota, and succeeding them, two formations Gangapur and Chikiala, whose inter-relationships are as yet uncertain.

### Yerrapalli Formation

This formation recognised by Jain, Robinson and Roy-Chowdhury (1964) succeeds the Kamthi Formation without any significant break (Sengupta, 1970). It is an essentially clay formation with subordinate sandstones. The clays may be variegated, but the dominant colours are red and violet; the latter is particularly characteristic of this formation. The associated rock types include 'lime-pellet' rocks (Robinson, 1964), fine-grained whitish calcareous sandstones, medium to coarse grey-white feldspathic calcareous sandstones, and a black calcareous sandstone whose black colour is due largely to the black colour of the calcite in it. These sand bodies occur as lenses of varying dimensions.

The clays and 'lime-pellet' rocks, sometimes also the sandstones, all yield vertebrate fossils. The fauna includes fishes, amphibians and reptiles; the common characteristic members are a capitosaurid amphibian *Parotosuchus* (*Parotosaurus*) and a kannemeyeriid dicynodont *Wadiasaurus*. Many of the faunal elements are restricted to this formation.

Although the contact with the underlying Kamthi may be gradational or inter-tonguing in places (Sengupta, 1970), such a zone when present is very narrow, and the boundary is almost always readily drawn at the first occurrence of the clays. The main difficulty, that is usually faced, is due to lack of exposure of the contact zone, but in general, the change in topography allows its reasonable inference.

## Bhimaram Sandstone

This formation, also recognised by Jain *et al.* (1964), forms a wide sandstone belt. It is essentially a sandstone formation, but may have within it some lenses and bands of red clays. Its lower part, well-developed in the southern part of the area, has a brown, sometimes violetish, coarse feldspathic sandstone which may be often pebbly and contain clay galls. The sandstones usually form rather flat but relatively higher ground which has a loose sandy soil. Sometimes ferruginous concretions and secondarily iron-enriched sandstone boulders are found scattered on the ground. The sandstones as well as the ground thus contrast with the Yerrapalli grounds.

The upper part of the Bhimaram Sandstone is more or less well-developed throughout. It consists of whitish and greywhite calcareous sandstones, fine to medium- and coarse-grained, often having patches of conglomerates whose pebbles appear to be largely of sandstones of similar lithology and clay galls; there may also be some pebbles of quartz and other rock fragments. Evidently these conglomerates are mostly of locally derived material. Towards the top, the sandstones become fine-grained and white in colour and are then overlain by the red clays of the Maleri Formation with a gradational but rapid contact. The soil of this zone is also sandy but firmer and whitish in colour. There is possibly a narrow clay zone between the two parts, but its persistence is uncertain because of the poor exposures.

## Maleri Formation

This is a red clay dominated formation with lime-pellet rocks and sandstones. The sandstones are usually fine- to medium-grained and white or greywhite in colour. Variants include a darker grey tougher sandstone with calcite cement, and may have abundant lime-pellets in it. Usually these pellets are small but in places, particularly in the upper part, there may be an abundance of irregular-shaped galls of greyish or greenish tough calcareous mudstones. Red and green claygalls are often present in the sandstones. The Maleri clays are usually a bright vermillion or crimson red in colour; they may also be greenish in places.

The 'lime-pellet' rocks usually occur as lenses of varying thickness and lateral extent, sometimes only a few centimetres thick and extending for not more than a few metres, and sometimes up to a few metres in thickness and extending laterally as a narrow ridge for some tens of metres.

The sandstones, too, have similar occurrences. But, some of the sandstones, though not much thicker, may be persistent laterally, and barring minor breaks, can be traced laterally for considerable distances, sometimes even for a few kilometres. The Maleri sequence can therefore be considered, roughly, as an alternating succession of sandstone and clay bands.

About half the width of the outcrop of the Maleri Formation is occupied by the lowest clay band, i.e., the clay band immediately above the Bhimaram Sandstone. It is therefore a particularly distinctive one in the field. The upper half may have numerous sandstone and clay bands.

Vertebrate fossil remains are fairly common in this formation, and include the rhynchosaur *Paradapedon* (*Hyperodapedon*) and the phytosaur *Parasuchus*, both characteristic members of King's Maleri. The fauna also includes some fishes, a metoposaurid amphibian, an armoured pseudosuchian and some early dinosaurs.

## Dharmaram Formation

The Dharmaram Formation has at its base a thick sandstone band. This sandstone band is followed up by more clay and sandstone bands. The sandstones bear superficial resemblance to those of the Maleri, and so too the red clays. But there are distinguishing features. The sandstones of the Dharmaram are generally medium- to coarse-grained and may in places be even gritty; the Maleri sandstones are fine- to medium-grained and almost never so coarse. Although lime-pellet rocks do occur in the Dharmaram, they are less frequent. However, the sandstones may contain abundant lime-pellets, claygalls and irregular-shaped galls of tough limy mudstones.

The wide basal sandstone band often forms low flat ridges with pale-brown loose sandy soil somewhat like the lower part of the Bhimaram Sandstone, contrasting nicely with those of the Maleri which have firm white sandy soil and form narrow ridges. The main problem in demarcating the boundary is due to poor exposures. Vertebrate fossils are from this formation, chiefly from the topmost clay band. None of the characteristic Maleri elements are present. The fauna consists chiefly of prosauropods and includes a large one which may be a plateosaurid (Kutty, 1969).

## Kota Formation

Succeeding the topmost clay band of the Dharmaram Formation is a coarse pebbly sandstone which grades up through fine-grained white sandstones into red clays; these red clays are in turn overlain by calcareous shales and limestones yielding the typical fish fauna of the Kota. In fact, there is a distinct faunal change at the pebbly sandstone (Kutty, 1969), and the base of this sandstone forms a well-defined lower boundary of the Kota Formation. Eastwards this sandstone is much thicker and the base is marked by a conglomerate with limestone pebbles (Rudra, 1982). The limestones are followed by some more red clays or ferruginous shales, and these are in turn succeeded by a sequence largely of sandstones and some shales. There is also probably a calcareous zone within this succession.

The presence of a conglomerate or a pebbly sandstone at the base and the abrupt change in the fauna is suggestive of a break in the continuity of the succession. However, it is possible that this break may not be of any great significance.

### Gangapur Formation

In the northwestern part of the area, the Kota Formation is overlain by the Gangapur Formation (Kutty, 1969). In the type area near the Cave Temple just north of the village of Gangapur it also corresponds to the 'Gangapur Beds' of King (1881). The formation has in its lower part some coarse and very coarse ferruginous sandstones with many pebble bands. These are then succeeded by an alternating sequence of sandstones and mudstones or silty mudstones. The mudstones characterise this upper part as also some ferruginous concretions that occur within or interbedded with them. The mudstones yield a good flora which is judged to be Early Cretaceous in age (Bose *et al.*, 1982; Ramakrishna & Ramanujam, 1987).

Eastwards, the outcrop of the Gangapur Formation ends against a fault which brings it against Triassic beds. However, even within this limited eastward extent, there is a clear indication of a coarsening of the rocks; the sandstones in its lower part become more pebbly and conglomeratic.

### Chikiala Formation

The Chikiala Formation is recognised only in the eastern part of the area and overlies the Kota Formation unconformably (King, 1881; Rudra, 1982). It consists of coarse and very coarse ferruginous sandstones and massive, locally extensive, but highly impersistent lenticular red clays, and some irregular occurrences of calcareous sandstones (Rudra, 1982). The sandstones and conglomerates may sometimes by very highly ferruginous. No fossils are known from the Chikiala Formation.

## RELATIONSHIP OF GANGAPUR AND CHIKIALA FORMATIONS

Although both the Gangapur and Chikiala formations are known to overlie the Kota Formation, there is nowhere any physical continuity between their outcrops. Their lithologies also differ considerably, so much so that their relationship to each other is obscure. There are no confirmed reports of fossils from the Chikiala. The Gangapur has a good Early Cretaceous flora, but neither such a flora nor an equivalent fauna of that age are known from the eastern part. Recently, Raivarman *et al.* (1985) have suggested that Gangapur is older than Chikiala on the basis of a fault which is claimed to affect the Gangapur but not the Chikiala. However, this evidence is not unequivocal, since the interpretation of the fault is at variance with that of Rudra (1982) who clearly indicates that the fault affects the Chikiala also.

## COMMENTS ON THE MAPPING PROBLEMS

The revised stratigraphy presented above is a vast improvement on the picture that King visualised more than 100 years ago. That it took so long is a reflection of the difficulties encountered in mapping these Gondwanas. Other than the problems due to the generally low relief of these grounds, and those due to the extensive soil cover and the generally poor nature of the exposures, there are three factors that contribute to the difficulties that are, in some sense, special to these Gondwana sediments. These are: (i) the lithological resemblances among rocks of different formations, (ii) the considerable amount of local lithological variations in addition to the regional variations, and (iii) the difficulties in recognising faults. Their compound effect can pose quite serious problems in the field.

It has already been pointed out how confusing lithological resemblances can be, from two sets of examples: (i) the Barakar-Infra-Kamthi group of rocks, and (ii) the red clay-sandstone formations of the Middle and Late Triassic. In the former, the distinction between the Barakar and the lithozones of the Infra-Kamthi were in the fine sediments and the carbonaceous or coaly material in them, which were less often exposed than the more dominant and similar looking sandstones in them. In the latter the difficulty was in differentiating the rather similar looking red clays and sandstones of these Triassic formations.

The confusion so caused is aggravated by the lateral lithological changes seen in them, both local and regional area. The former associated with the variety of depositional environments under the fluvial regime is our main concern as it affects the local outcrop pattern. Coupled with the poor nature of exposures, they present difficulties in tracing beds along their strike; the Maleri amply illustrates this problem. It is made worse by the fact that faults leave little direct evidence on these soft Gondwana rocks, and the normally irregular outcrop pattern of the different lithologies tends to camouflage the shifts of beds due to the faults. It should be evident that, in such circumstances, anything but a detailed mapping can lead to a confused characterisation of the units mapped, and that such a characterisation of a unit may include in it characters that might truly belong to other units. Therefore, it should be clear that no evidence that might help clarify the situation is to be ignored. This includes fossils.

Fossils play a vital supplementary role in mapping. Their use does not make a litho-stratigraphic unit, that is being mapped, a biostratigraphic unit. At best it can become a time stratigraphic unit. The code of stratigraphic nomenclature only demands that a rock stratigraphic unit should not be distinguished *only by its* fossils; it does not demand that its fossil content is to be completely ignored.

It may not be out of place to emphasise here that the formations Yerrapalli, Bhimaram Sandstone, Maleri and Dharmaram are all lithostratigraphic units. They have been characterised and mapped on their lithological distinguishing characteristics, and their boundaries are defined and distinguished on lithological grounds. That some of them have their own distinctive faunas is no disqualification. It is important to note that these formations are not only mappable, but have actually been mapped over a considerable distance (Map 1).

## COMMENTS ON THE REVISIONS OF RAIVARMAN *et al.*

The area covered by Raivarman *et al.* (1985) is very large, covering the entire PG Valley and extending further north to include the contiguous Wardha Valley, and the scope of the work is also quite extensive. However, the interpretations of Raivarman *et al.* differ in many respects from all earlier accounts. To mention a few, (i) their mapping has produced a stratigraphic succession which has a number of new formations whose relationship to other existing versions are far from clear, (ii) all the formations are bounded by unconformities and overlaps in contrast to the picture that has been emerging in recent times, of possessing a continuous sequence through Permian and Triassic, (iii) the sequence is interpreted as one marked by repeated marine influences, contrasting with the widely accepted view of being fluvial and lacustrine deposits with an early glacial or glaciofluvial phase, (iv) the tectonics affecting these sediments is claimed to involve thrusting, while previously only normal faulting had been envisaged; and (v) the biota is almost totally ignored.

In so far as the part of the PG Valley under consideration here is concerned, certain inconsistencies with earlier observations are apparent. A few examples are cited below: (1) Raivarman *et al.* claim that there are no coal outcrops in the area, and that the Barakar Formation does not have any surface outcrops and is strictly a sub-surface formation. This is incorrect as coal outcrops do exist. There are also reports of coal occurrences in the literature (King, 1881; Rao, 1982), and an open-cast mine further confirms this point. (2) The Dharmaram Formation is considered by Raivarman *et al.* as a member of their Maleri Formation claiming that it is only traceable for about 17 km. Suffice it to say that the Dharmaram Formation has indeed been recognised and mapped all along from where Kutty (1969) originally mapped it, southeastwards for over 60 km, to near Sironcha (Rudra, 1982; Bandyopadhyay & Rudra, 1985; Map 1 of this paper). An examination of the geological map of Raivarman *et al.* indicates that, in different parts of the area, part or whole of the Dharmaram Formation have been mapped within different formations of theirs; namely, in the 'Kota Formation' west of Wadala, in the 'Maleri Formation' just to the east of Wadala, in a newly proposed 'Tarvai Formation' in the area southeast of Metpalli, in a newly proposed 'Maner Formation' (which appears to be equivalent to the Kamthi Formation) in the neighbourhood of Sironcha and in the Chikiala Formation to the southeast of Sirpur.

It may not be out of place to recall that one of the major controversies, that affected the stratigraphy of this area, concerned with the 'Gangapur beds' of King (1881). A comparison of King's geological map with that presented here (Map 1) suggests that King's problems arose from considering the sandstones of the Dharmaram Formation as the southeasterly equivalents of the sandstones of the Gangapur Formation.

## VERTEBRATE FAUNAS

The study of fossil vertebrates from the PG Valley has assumed special importance for several reasons. Firstly, the valley has a fairly unbroken succession of Gondwana rocks, albeit the two breaks in the upper subdivision. Secondly, it is unique among the Gondwana in having a number of distinct vertebrate faunas. Already five faunas are known, all from the northern part of the valley; these are from the Infra-Kamthi lithozone 3, Yerrapalli, Maleri, Dharmaram and Kota. And, there are indications that there might be two more faunas, one from the Lower Kamthi and the other from the Bhimaram. Thirdly, there is sufficient overlap of this faunal sequence with those from the other Gondwanaland areas on the one hand and the Laurasian sequences on the other, thus providing a tie-up of the former with the latter. Jain and Roy Chowdhury (1987) have recently given an account of the vertebrate faunas from PG Valley and hence the following account is somewhat abbreviated.

*The Infra-Kamthi Fauna*—The vertebrate fauna from the Infra-Kamthi lithozone 3 is yet to be described in detail, but is known to be largely an endothiodont-dicynodont complex with an odd captorhinomorph in it (Kutty, 1972). Also, it has two forms which are close to *Endothiodon* and *Cistecephalus*, both typical of the *Cistecephalus* zone of the Karroo Sequence of South Africa. The fauna is readily correlated to that zone and can be dated as early Late Permian.

*The Yerrapalli Fauna*—The Yerrapalli fauna is known to consist of a saurichthyd fish (Jain, 1984), dipnoan *Ceratodus* (Chatterjee, 1967), temnospodyl *Parotosuchus* (Roy Chowdhury, 1970a), two dicynodonts—*Wadiasaurus* and *Rechnisaurus* (Roy Chowdhury, 1970b), rhynchosaur *Mesodapedon* (Chatterjee, 1980a), a cynodont (Chatterjee *et al.*, 1969), at least two archosaurs (one proterosuchian and one rauisuchid) and a protorosaurian (Jain & Roy Chowdhury, 1987). The fauna is listed in Table 3.

**Table 3—Fossil vertebrates from the Yerrapalli Formation**

| Faunal List | Geological Range |
|---|---|
| FISHES | |
| Chondrostei | |
| *Saurichthys* sp. | Triassic |
| Dipnoi | |
| *Ceratodus* sp. | Mesozoic |
| AMPHIBIANS | |
| Capitosaurs | |
| *Parotosuchus rajareddyi* | Early or Middle Triassic |
| REPTILES | |
| Dicynodonts | |
| *Wadiasaurus indicus* | Middle Triassic |
| *Rechnisaurus cristarhynchus* | Middle Triassic |
| Cynodonts | |
| Trirachodontid teeth | Early or Middle Triassic |
| Rhynchosaurs | |
| *Mesodapedon kuttyi* | Middle Triassic |
| Proterosuchians | |
| Undescribed genus and species | Early to Middle Triassic |
| Pseudosuchians | |
| Undescribed genus and species | Triassic |
| Protorosaurs | |
| Undescribed genus and species | Triassic |

Among the Yerrapalli dicynodonts, kannemeyeriid *Wadiasaurus* shows advancement over Early Triassic *Kannemeyeria* and could have evolved from the latter (Bandyopadhyay, 1985). Moreover, *Wadiasaurus* shows similarity in several respects with kannemeyeriid genera of definite Middle Triassic age. The dental characters of rhynchosaur *Mesodapedon* show the evolutionary stage attained by Middle Triassic *Stenaulorhynchus* (Chatterjee, 1980a). Colbert (1984) has recently drawn attention to the Yerrapalli rauisuchid showing Middle Triassic affinities. Similarly, Chatterjee (1980b) would like to consider the Yerrapalli protorosaurian as showing Middle Triassic affinities in his scheme of eosuchian evolution. To sum up, the Yerrapalli fauna shows very strong Middle Triassic connections and its comparison with similar faunas found elsewhere in the world suggests an Anisian age.

*The Maleri Fauna*—The Maleri fauna is characterized by the presence of a dipnoan, a xenacanth (pleuracanth), a temnospondyl, a rhynchosaur, a phytosaur, a coelurosaur, a protorosaur, an aetosaur and a cynodont. The better known members of the fauna are temnospondyl *Metoposaurus* (Roy Chowdhury, 1965), rhynchosaur *Paradapedon* (Chatterjee, 1974), phytosaur *Parasuchus* (Chatterjee, 1978), protorosaurian *Malerisaurus* (Chatterjee, 1980b) and cynodont *Exaeretodon* (Chatterjee, 1982). Other members of the fauna include dipnoan *Ceratodus* (Miall, 1878; Jain, 1968) and xenacanth *Xenacanthus* (Jain, 1980). A coelurosaurian dinosaur, *Walkeria* (Chatterjee, 1987) is known from skull and some postcranial material. A few more forms, including an aetosaur, two more phytosaurs and one more temnospondyl are suspected to be present in the Maleri fauna as suggested by fragmentary remains (Lydekker, 1885; Huene, 1940). A listing of the better known members are given in Table 4.

The temnospondyl and reptilian groups suggest an early Late Triassic age and the evolutionary level of the phytosaur particularly points to a Carnian age. The suggestion made earlier (Romer, 1960) that the rhynchosaur may indicate a Middle Triassic age has been treated by Chatterjee (1980a) to show that the Maleri rhynchosaur is undoubtedly of Late Triassic age. This view has been further reinforced by Colbert (1984), who has compared the Maleri fauna with those of the Keuper of Europe and the Late Triassic Dockum and Chinle of North America.

*The Dharmaram Fauna*—The vertebrate fauna from the Dharmaram Formation is still not described in detail but a preliminary report indicates the presence of an essentially dinosaur fauna. There are atleast two saurischians, both prosauropods; one is a

**Table 4—Fossil vertebrates from the Maleri Formation**

| Faunal List | Geological Range |
|---|---|
| FISHES | |
| Dipnoi | |
| *Ceratodus virapa* | Mesozoic |
| *C. hunterianus* | Mesozoic |
| *C. hislopianus* | Mesozoic |
| *C. nageswari* | Mesozoic |
| Subholostean | |
| Unnamed genus and species | |
| Xenacanth | |
| *Xenacanthus indicus* | Late Triassic |
| AMPHIBIANS | |
| Metoposaurs | |
| *Metoposaurus maleriensis* | Late Triassic |
| REPTILES | |
| Cynodont | |
| *Exaeretodon statisticae* | Late Triassic |
| Rhynchosaur | |
| *Paradapedon huxleyi* | Late Triassic |
| Eosuchian | |
| *Malerisaurus robinsonae* | Late Triassic |
| Phytosaur | |
| *Parasuchus hislopi* | Late Triassic |
| Pseudosuchian | |
| Scutes similar to *Typothorax* | Late Triassic |
| Coelurosaur | |
| *Walkeria maleriensis* | Late Triassic |
| Prosauropod | |
| cf. *Massospondylus* sp. | Late Triassic |

large plateosaurid and the other a small thecodontosaurid. In addition, there is an ornithischian and a sphenosuchid in the fauna. In discussing the age of the Dharmaram fauna, Kutty (1969) noted that the changes between the Dharmaram and Maleri faunas are very similar to those found between the Knollenmergel and Rhatsandstein on the one hand and the Keuper horizons below on the other of the type Triassic succession of Germany. Hence the Dharmaram fauna was provisionally considered to be of Late Norian to Rhaetian age.

*The Kota Fauna*—The Kota fauna is characterized by the presence of three semionotids, a coelacanth and two pholidophorid fishes. The semionotids, *Paradapadium* and *Tetragonolepis* are restricted to the Liassic (Jain, 1973). The Kota *Lepidotes* is also close to *L. elvensis* from the European Liassic (Jain, 1983). The coelacanth, *Indocoelacanthus*, though not an age marker, is the only example of the group from India (Jain, 1974a). Pholidophorids, well-represented in the European Liassic, are also suggestive of an Early Jurassic age for the Kota Formation (Yadagiri & Prasad, 1977).

The sauropod remains from the Kota Formation are quite well-known. The best known member is *Barapasaurus*, which is claimed as one of the oldest known sauropod in the world (Jain *et al.*, 1975, 1979). In addition, Yadagiri *et al.* (1979) have also suggested the presence of a second dinosaur which is "closer to prosauropods than sauropods." *Campylognathoides*, a pterosaur, known from Liassic of Germany has also been found from the Kota Formation (Jain, 1974b). Fragmentary crocodilian remains from the Kota (Owen, 1852) have been referred to the family Teleosauridae and it has been suggested (Buffetaut, 1979) that the Kota crocodiles may be the earliest representatives of the family.

Discoveries of Early Jurassic mammals from the Kota Formation have been recently reported. On the basis of isolated teeth, Datta (1981) erected *Kotatherium* and Yadagiri (1984) erected *Trishulotherium* and *Indotherium*, all assigned to kuehneotherid symmetrodonts. An amphidontid symmetrodont, *Nakunodon*, has also been identified from the Kota Formation (Yadagiri, 1985). The precise relationship of these teeth with other symmetrodonts is at present quite uncertain. However, in view of the paucity of these early mammals from Gondwanaland and the sparse records of Early Jurassic mammals all over the world. the discoveries of such remains are extremely important. A list of the Kota fauna is given in Table 5.

Yadagiri (1986) has recently given an account of a number of microvertebrates from " the clays immediately underlying the fossiliferous limestone" of the Kota Formation near Paikasigudem (19°16'N, 70°31'E). These include a hybodont shark (*Lonchiodon*), a perch (genus indet.), a pelobatid

**Table 5—Fossil vertebrates from Kota Formation**

| Faunal List | Geological Range |
|---|---|
| FISHES | |
| Semionotidae | |
| *Lepidotes deccanensis* | Liassic |
| *Paradapedium egertoni* | Liassic |
| *Tetragonolepis oldhami* | Late Liassic |
| Pholidophoridae | |
| *Pholidophorus kingii* | Liassic |
| *P. indicus* | |
| Coelacanthidae | |
| *Indocoelacanthus robustus* | Uncertain |
| REPTILES | |
| Dimorphodontidae | |
| *Campylognathoides indicus* | Liassic |
| Sauropod dinosaur | |
| *Barapasaurus tagorei* | Early Jurassic |
| Teleosauridae | |
| Scutes and other fragments | Uncertain |
| MAMMALS | |
| Symmetrodonts | |
| *Kotatherium haldanei* | Uncertain |
| *Trishulotherium kotaensis* | Uncertain |
| *Indotherium pranhitai* | Uncertain |
| *Nakunodon paikasiensis* | Uncertain |

frog (genus indet.), a sirenian urodele (genus indet.), a sphenodontid (genus indet.) and a varanid reptile (*Paikasisaurus*). Except for the hybodont and the sphenodont, all the other groups are known only from post-Jurassic horizons (Andrews *et al.*, 1967; Panchen, 1967; Appleby *et al.*, 1967); in fact the percoids and varanoids are not known earlier than the Maestrichtian. The apparent occurrence of such an assemblage in beds below the Kota limestones which yield the Liassic fish fauna is paradoxical. The percoids, pelobatids and urodeles are characteristic members of the Deccan Intertrappean fauna (Sahni, 1984). It is generally believed that these areas were once covered by the Deccan Traps and its associated Intertrappean beds, and at present they occur not too far to the west from here. It is not impossible that the observed fossil assemblage may be the result of post-Gondwana contamination.

## POTENTIAL FOR TWO MORE FAUNAS

In addition to these five faunas, we noted the potential likelihood of the existence of two other faunas in this sequence. One of them is from the Lower Kamthi (*sensu* Sengupta, 1970). Two reptilian fossil specimens were recently discovered from the basal siltstones of this Lower Kamthi by some local villagers, from a quarry. These specimens are unfortunately not available for study, as the villagers have, believing them to be representations of a deity, started worshipping them and have constructed temples around them. More importantly, they cannot also be prepared to establish their true affinities. One specimen, in two counterparts, shows a near complete articulated reptilian skeleton with only the anterior end and part of the tail missing. The specimen is a little over 40 cm long. Only the occiput of the skull is visible which is low and wide. It is likely to be a dicynodont but does not seem to be either *Lystrosaurus* or any of the later Triassic forms. It may possibly belong to the fauna that is known from the Infra-Kamthi lithozone 3, but it is not unlikely that it belongs to a later Permian fauna, i.e., the equivalent of the *Daptocephalus* Zone of the Karroo.

The second potential fauna is from the Bhimaram Sandstone. This formation has yielded some fragmentary material which indicate the presence in it of at least an amphibian and a dicynodont. There are some indications that this dicynodont may be different from the ones seen in the Yerrapalli. For example, the snout seems to be far more pointed than any seen in the Yerrapalli specimen. It is possible that this might be part of a late Middle Triassic (Ladinian) fauna, as is suggested by its stratigraphic position. But, for the present, it is speculative and inconclusive.

## CORRELATION

The discussions so far bring out two important attributes of the Gondwana sequence of the PG Valley. Firstly, it has an almost unbroken succession from Early Permian through Triassic and with a small break into the Early Jurassic. Secondly, it possesses a fairly good sequence of a number of vertebrate faunas of considerable stratigraphic value. In both these respects, it is somewhat unique from among the many Gondwana outcrops in India. This vertebrate sequence not only allows a correlation of the Gondwana of the PG Valley with other well known vertebrate sequences of the corresponding periods from different parts of the world (Table 6), but it also provides useful tie-ups between the European and North American sequences on the one hand and the African and South American sequences on the other.

While the PG Valley sequence allows such world-wide correlations, its correlation with the sequences from the various other Gondwana outcrops in India is far more difficult and speculative. Only two formations, Talchir and Barakar, maintain more or less uniform lithological characteristics in all the outcrops. The post-Barakar succession is variable from outcrop to outcrop and an exclusively lithological correlation becomes just an academic exercise. That, correlations based on lithological similarities alone, even intra-basinal, can lead to misleading interpretation is evident from many examples. It was already pointed out earlier how the similarity of the sandstones of the succession between the Talchir and Kamthi formations led to varied interpretation of the Barakar (Sengupta, 1970; Raivarman *et al.*, 1985). The problem of differentiating one red-clay-dominated formation from another is an age-old one. Fox (1931) visualised the Lower Gondwana Motur Formation and Upper Gondwana Denwa Formation of the Satpura Basin as one and the same formation because of their gross lithological similarities, and pictured their underground continuity with all the intervening beds sitting on them and therefore making them younger. Crookshank (1936) showed such an interpretation to be untenable.

An idea similar to that of Fox (1931) has recently been postulated by Dutta (1987) who suggests that the ridge-forming Kamthi Formation was not stratigraphically between Infra-Kamthi and Yerra-palli, but rested unconformably upon a Triassic sequence of red clays and sandstones starting from the upper lithozone of the Infra-Kamthi. Dutta

**Table 6—Correlation of some important vertebrate-bearing sequences of the Permian, Triassic and Early Jurassic**

| AGE | | | INDIA (P.G.VALLEY) | SOUTHERN AFRICA | ARGENTINA | WESTERN N.AMERICA | GERMANIC BASIN | CHINA | U.S.S.R. |
|---|---|---|---|---|---|---|---|---|---|
| 188 m.y. | JURASSIC | EARLY | KOTA | DRAKENSBERG VOLCANICS; CAVE SANDSTONE (CLARENS FM) | SERRAGERAL VOLCANICS | GLEN CANYON GROUP | | LOWER LUFENG | |
| 208 | TRIASSIC | LATE | DHARMARAM; MALERI | RED BEDS (ELLIOT FM); MOLTENO | LOS COLORADOS; ISCHIGUALASTO | CHINLE-DOCKUM | KEUPER: RATSANDSTEIN, KNOLLENMERGEL, STUBENSANDSTEIN, BUNTEMERGEL, SCHILESANDSTEIN, GIPSKEUPER, LETTENKHOLE | LOWER LUFENG; ? ? ? ? ? ? ? | |
| | | MIDDLE | BHIMARAM SANDSTONE; YERRAPALLI | MOLTENO | LOS RASTROS CHANARES ISCHICHUCA | | MUSCHELKALK | KELAMYI; (MARINE) ERMAYING | BUKABAI; DONGUS |
| | | E. | KAMTHI | BEAUFORT: CYNOGNATHUS ZONE, LYSTROSAURUS ZONE | PUESTO VIEJO | MOENKOPI | BUNTSANDSTEIN | SHAOFANGGOU JIUCAIYAN; HESHANGGOU | VETLUGA |
| 245 | PERMIAN | LATE | INFRA KAMTHI | BEAUFORT: DAPTOCEPHALUS ZONE, CISTECEPHALUS ZONE, TAPINOCEPHALUS ZONE | | FLOWER POT; SAN ANGELO | ZECHSTEIN; KUPFERSCHIEFER | LOWER CANGFANGGOU U JIJICAO | N. DVINA; DINOCEPHALIAN COMPLEX |
| 286 | | EARLY | BARAKAR; TALCHIR | ECCA; DWYKA | | CLEAR FORK; WICHITA | ROTLIEGENDE | | |

therefore suggested a Lower Jurassic age to the Kamthi Formation. The arguments for his conjecture pivoted on the observation that the pole position inferred from the palaeomagnetic data from the Kamthi was inconsistent with the Apparent Polar Wander Path for India (APWP) if the age of the Kamthi were Late Permian to Early Triassic; but a Jurassic age for the Kamthi would make the observation consistent with the APWP. It can be demonstrated unequivocally that field relations do not support such a conjecture. Perhaps the palaeomagnetic data from the Kamthi Formation is not to be related to the age of the Kamthi, but to its ferrugination which is post-diagenetic and secondary (Sengupta, 1970). The Jurassic—or may be even later—age suggested by Dutta (1987) would then refer to this secondary ferrugination.

The other means of correlation that have relevance in this context are the fauna, mainly the vertebrates, and the flora; but both, as of now, have limited usefulness for varied reasons discussed below.

Outside the PG Valley the other Gondwana outcrops have yielded relatively little in the way of vertebrates. Among them, only three formations have yielded anything like a fauna; all others being isolated occurrences, either known from solitary specimens or fragments. These three are, an Early Permian fish-amphibian fauna containing *Archegosaurus* from the *Gangamopteris* beds of the Kashmir marginal facies, an Early Triassic *Lystrosaurus* Zone fauna from the Panchet Formation of the Damodar Valley and a early Late Triassic amphibian reptilian fauna from the Tiki Formation from the South Rewa Gondwana Basin. The Tiki fauna can be equated with that from the Maleri Formation. In the Satpura Gondwana Basin, there are, however, two formations —Bijori and Denwa—which are known to contain distinctive amphibians. The former is known from a single specimen of Permian *Gondwanasaurus* while the latter has so far yielded only fragments of a poorly known *Parotosuchus* of Middle Triassic affinities. The other occurrences are all isolated ones and some outcrops have no known vertebrate occurrences at all. Thus in the Indian context, the vertebrates provide at present very limited control in these inter-outcrop correlations. Under such circumstances, it is probably premature to attempt at a bio-stratigraphic zonation based on vertebrates. However, a very useful beginning on this line has been made by Shah, Singh and Sastry (1971) and followed up by Sastry, Acharyya, Shah, Satsangi, Ghosh and Singh (1979) using vertebrates. No further attempt is made here to extend this bio-stratigraphic zonation.

There are very few detailed studies on the floras from many formations of the PG Valley Gondwana Sequence. There is also a problem in relating some of the earlier reports of plant occurrences to the revised stratigraphy because of the lack of precise locations. It will be of importance if detailed floral assemblages from this area are worked out afresh in accordance with the revised stratigraphic succession. This will not only provide an independent floral succession for this outcrop which can be reliably related to the revised geology, but it will also provide a much needed and necessary tie-up between the floral succession on the one hand and the vertebrate faunal succession on the other.

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